# CHIRP-BASED METHOD AND APPARATUS FOR PERFORMING PHASE CALIBRATION ACROSS PHASED ARRAY ANTENNA

## FIELD OF THE INVENTION

**[0001]** The present invention relates in general to communication systems and subsystems therefor, and is particularly directed to a new and improved, chirp-based arrangement for deriving a very accurate measure of phase variation through a reference frequency transport cable of a relatively physically large phased array antenna architecture, such as a spaceborne synthetic aperture radar system.

## BACKGROUND OF THE INVENTION

**[0002]** Relatively large phased array antenna architectures, such as but not limited to spaceborne, chirped synthetic aperture radar systems, typically contain a multiplicity of transmitters and receivers distributed across respective spaced apart arrays. In such a system, a common reference frequency is customarily supplied to all transmit and receive element groups of the array. As such, there is the issue of how

to take into account phase shift associated with variations in the substantial length of signal transport cable that links a reference frequency source, used at one transmit/receive location in the array, with the a remote transmit/receive portion of the array.

**[0003]** Because terrestrial open loop calibration of the system suffers from the inability to take into account variation in temperature along the transport cable due to changes in sun angle, and variations in obscuration by components of the antenna support platform in the antenna's space-deployed condition, it has been proposed to perform temperature measurements at a number of locations along the cable and provide phase compensation based upon the measured values. A drawback of this approach stems from the fact that there are non-linearities within the cable, so that over different temperatures it is necessary to employ a larger number of values in the calibration table. In addition, because this scheme employs multiple measurement points along the cable, there are associated variations in loading which, in turn, introduce separate amounts of phase shift to the reference frequency signal.

## SUMMARY OF THE INVENTION

**[0004]** In accordance with the present invention, the above discussed transport cable-based phase variation problem is effectively obviated by injecting a direct digital synthesized RF chirp signal into the signal transport path from the receive end of the path. The

injected RF chirp signal is transmitted over the signal transport path, and then reflected from an upstream bandpass filter (tuned to the RF frequency reference signal) at the reference source end of the antenna, so as to return to the remote portion of the antenna where it was originally injected. Via a downstream bandpass filter (tuned to the passband of the chirp), a reflected RF chirp signal receiver at the receive remote end of the path extracts energy in the reflected RF chirp return signal.

**[0005]** The output of the RF chirp signal receiver is coupled to a correlator of a delay locked loop, which correlates energy of the returned RF chirp signal with energy in an auxiliary RF chirp signal, the generation of which is delayed with respect to that of the RF chirp signal injected into the signal transport path. The delay of the auxiliary RF chirp signal is adjusted to maximize the output of the correlator and provide an output representative of phase delay through the signal transport path.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** The single Figure diagrammatically illustrates an embodiment of the phase calibration architecture of the present invention.

## DETAILED DESCRIPTION

**[0007]** Before describing in detail the chirp-based cable calibration arrangement of the present invention, it

should be observed that the invention resides primarily in a modular arrangement of conventional communication circuits and components and an attendant supervisory controller therefor, that controls the operations of such circuits and components. In a practical implementation that facilitates their being packaged in a hardware-efficient equipment configuration, this modular arrangement may be implemented by means of an application specific integrated circuit (ASIC) chip set.

**[0008]** Consequently, the architecture of such arrangement of circuits and components has been illustrated in the drawings by a readily understandable block diagram, which shows only those specific details that are pertinent to the present invention, so as not to obscure the disclosure with details which will be readily apparent to those skilled in the art having the benefit of the description herein. Thus, the block diagram illustration is primarily intended to show the major components of the invention in a convenient functional grouping, whereby the present invention may be more readily understood.

**[0009]** Attention is now directed to the single Figure, wherein an embodiment of the chirp-based cable calibration arrangement of the present invention is diagrammatically illustrated. As shown therein, a reference frequency signal generator 10, such as a very stable oscillator that is co-located with one transmit/receive portion of the array 20, is coupled through a bandpass filter 30, which is centered on the

output frequency of the reference frequency signal generator, to a first end 41 of a length of cable 40, phase variations through which, such as associated with temperature variations along the cable, are to be compensated. The far or remote end 42 of the cable 40 is coupled through a diplexer 50 to a transmit/receive portion of the antenna array 60 and associated receive array processing circuitry 70.

**[00010]** As pointed out above, cable 40 can be expected to be subjected to temperature variations (and accompanying variations in cable length/transport delay) along its length due to changes in temperature, such as those associated with changes in sun angle, and obscuration by components of the antenna support platform. The present invention solves this problem and provides an accurate measure of cable transport delay, by injecting, from the downstream or receive end 42 of the cable, a chirp signal that propagates up the cable, is reflected from the bandpass filter 30 and returns back down the cable to a reflected signal processor, that determines the cable delay.

**[00011]** To this end, the invention employs direct digital synthesizer 80 that generates a phase continuous chirp signal that is coupled into the cable by means of a coupler 90 at the downstream end of the cable. Operating in parallel with and driven by the same clock as DDS chirp generator 80 is a numerically controlled chirp generator 100, the output of which is coupled to a first input of 111 of a digital correlator 110. A second input

112 of correlator 110 is coupled to receive a digitized version of the reflected chirp signal that has been returned to the downstream/ remote end of the cable. For this purpose, a coupler 120 is installed adjacent the downstream/receive end of the cable. The output of the coupler is coupled through a bandpass filter 130 and associated gain stage 140 to an analog-to-digital (A/D) converter 150 to the second input 112 of the correlator 110. The output of the correlator 110 is coupled to a delay calculation unit 160, which outputs a digital delay word value in accordance with the degree of correlation produced by correlator 110. The delay word value, in turn, is coupled to the chirp generator 100, and is used to adjust the amount of delay in the numerically controlled chirp signal produced by generator 100 to maximize the output of correlator 110. When this happens the value of the delay word produced by delay calculation unit 160 represents the total (upstream and return) delay through the cable. Within the unit 160 this value is divided by two and supplied over an output link 161 as a digital value representative of the length and associated transport delay through the cable to the receive array processing circuitry 70. The receive array processing circuitry is now able to adjust the phase of the reference frequency to take into account the length of (delay through) the cable 40.

**[00012]** It should be noted that the rate of change of cable length is considerably slow relative to the

processing time associated with the operation of the invention. As pointed out above, in a spaceborne environment, changes in cable length due to temperature are ambient effects, such as sun angle and obscuration by components of the antenna support platform. Such changes are very slow relative to the high signal transport and processing speeds associated with the generation of the chirp and correlation processing of the chirp return, which may be in the pico to microsecond range.

**[00013]** While we have shown and described an embodiment in accordance with the present invention, it is to be understood that the same is not limited thereto but is susceptible to numerous changes and modifications as known to a person skilled in the art. We therefore do not wish to be limited to the details shown and described herein, but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.